Retrocomputing, Archival Research, and Digital Heritage Preservation: A Computer Museum and iSchool Collaboration

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Abstract

This article discusses the potential contributions of lay members of the public to the dialogue around the *data/information/knowledge life-cycle* in a community technology museum, the Goodwill Computer Museum in Austin, Texas. Through an examination of the museum's collaboration with the University of Texas School of Information, the article addresses the situation that arises when a museum is created by non(museum)-professionals who control considerable expertise in the subject field, and explores how the presence and collaboration of volunteers allows the museum to serve as a laboratory setting for the participation of academic researchers in the field of digital heritage preservation.

> A computer is a machine with a soul, and it must be kept alive with its operating environment to show its abilities and the contemporary state of the art.
>
> —Burnet and Supnik, 1996, p. 33

> Sometimes I feel like we're making medieval armor.
>
> —Russell Corley, personal communication, July 30, 2010

Introduction: From Digital Preservation to Preservation of Digital Heritage

For years the digital archiving and digital preservation communities have discounted the idea that the way to preserve old digital objects is to preserve old computers. Migration and emulation are seen as the two ends of a continuum of preservation, but both have assumed new, current hardware and continued porting of digital objects through sequential states of the computing environment as the basis for digital preservation. Even

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if digital preservationists are as yet unwilling to bring on board the emergent new-media perceptions of the importance of media materiality, an unavoidable challenge lies at the beginning of the chain of digital preservation: the bits have to be captured into a current preservation space, and to recover them we have to be able to read them and copy them, which cannot be done without old hardware. In that sense at least, an actionable understanding of the original context of creation is important to preserve.

In many cases recent legacy media can (at least for the present) be read, but this is more difficult with media from the earliest, experimental period of personal computing before it became narrowed to a few commodity choices. For digital materials created through the mid-1980s, would-be preservationists are faced with a welter of incompatible operating systems, file formats, and media formats, used with abandon and without consideration for the future by people who simply welcomed this new and more efficient way to create and were not concerned about how to communicate what they created (Ceruzzi, 1998). For digital materials produced in such contexts and deemed worthy of preservation in archives today because of their cultural or technical value, we need to be able not only to read and copy them, but also to recover the performance of the environments themselves in order to understand the environment in which the creation was done.[1] Hence archivists also need to be able to work with noncurrent operating systems, peripheral drivers, communications protocols, and machine specifications, and at a minimum to capture the performance of all these objects in action through screenshots and videos, or at a maximum to capture the entire digital ecology of running systems. We do not yet know in detail how to do all this, so there is a good deal of research to be done in this field. For the past seven years our research in this area at the University of Texas has been proceeding through the medium of reflective laboratory practice in my course on digital archiving and preservation, as we have set up and operated a digital repository and learned how to capture and preserve digital collections in it.

This article describes how we sought knowledge to apply to the task of capturing digital materials for preservation from a local computer history museum, where we discovered a reservoir of relevant preservation knowledge, available through what has come to be called the "retrocomputing" community and partly institutionalized in the practices of computer restoration in museums of computing. It then describes how we are building a collaboration between the Goodwill Computer Museum and the University of Texas, engaging the sharing of expertise and nurturing the emergence of a hybrid community of practice. Our experience points to the value of the collaboration of academic and nonacademic communities for the tasks of preservation of digital heritage broadly considered.

Retrocomputing as a Reservoir of Knowledge—in the Wild and at the GCM

Almost the whole of computer history is a temporal target from which living expertise is still available—explicit documented knowledge, yes, but also the tacit knowledge embedded in the design and use of both hardware and software, much like Peter Naur's (1985) "theory of the program," constructed by teams of programmers and used by them in the maintenance of their program over its lifespan. It is possible to turn to and make use of Naur's discipline of participatory design, drawing on the skills of older engineers and dedicated collectors and experimenters who have come together both physically and virtually in what has been called the "retrocomputing" community (Wikipedia, 2010).

Although there are many ways to categorize people and activities that come under this heading, the crucial elements that bound it are: (a) amateurism, in that the time spent on legacy computing is not generally compensated, although many now involved in the community are presently or were formerly employed in the computer industry; (b) technological skill, acquired through education, professional experience, or personal study; and (c) the persistent interest that springs from a sincere identity with and interest in the field. Members of this community range from retired professionals determined to document and preserve hardware systems on which they worked and in whose importance they believe (Burnet & Supnik, 1996), to young gaming experts so eager to experience videogames created before they were born that they are willing to spend considerable time gathering and restoring the requisite hardware and software. Older members may be associated with other communities similarly devoted to technological tinkering, like amateur radio; youthful members may be interested in working with new media forms.

Retrocomputing is not a new phenomenon. Since before the earliest days of personal computing, people have collected computers for a variety of reasons, but personal computers have been of particular interest. As Sherry Turkle has suggested in several of her works, pointing to the relationships that users of personal computers developed with their machines, the first enthusiasts for the earliest primitive machines often had skills in electronics and were very interested in hands-on work (1985, 2007). Collecting has often begun with a simple reluctance to part with an older machine once replaced, since in terms of space and cost, personal computers have not been burdensome to collect; in eliciting computing autobiographies from students, I have heard of attics and garages populated with old computers. Collecting computers shares many aspects of collecting in general, including a focus on the object and the importance to the collector of the kind of objects collected (Pearce, 1994, Pt. 2). But actually working with hardware as well as collecting it is key to this interest. The temporally older cohorts of retrocomputing tend to be localized in areas where there has been some manifestation of the technology industry and a corresponding accumulation of electronics parts surplused by manufacturers, while younger participants have benefited by the broad availability of consumer electronics in the last twenty years.

Nor is collecting limited to hardware. At the introduction of microprocessors, nearly the entire field was made up of people who saw the potential of microchips to drive actual computing machines instead of serving merely as embedded electronics. At the beginning there were kits similar to amateur radio electronics kits, some with excellent documentation; there were flyers and mimeographed catalogs handed out at electronics swap meets; there were microcomputing clubs where people met to experiment; there were bulletin boards accessed via modem. And from as early as there was something to program with, people wrote programs to fill what was at first a yawning void, which would persist until what would by then be called personal computers penetrated business settings (Ceruzzi, 1998, chaps. 7–8; Campbell-Kelly & Aspray, 2004, Pt. 4). Enthusiasts still maintain online compendia of a wide range of user-crafted software for early machines, made available freely for downloading. There still exists, therefore, a considerable reservoir of historical and documentary material for early microcomputing of the 1970s–80s, and there is a large group of people who collect and work with this material for the sake of their own interest.

Perusing online retrocomputing sites shows that groups of likeminded individuals sometimes get together to found a small museum, usually in someone's home or sometimes in rented space, but such museums seldom last long because the participants do not have the time, resources, or long-range purpose to sustain them. In Austin we are lucky to have an emerging institution that is succeeding in providing a physical and institutional locus for the exercise and preservation of retrocomputing interests and skills. The Goodwill Computer Museum (GCM) is an institution with a ten-year history of development and a four-year formal existence; it has dedicated space, skilled volunteers, and a salaried director. Since its informal beginnings, its collections have mostly come from the rich Austin electronics recycling stream processed by the Goodwill Industries of Central Texas's Computerworks Division. The commitment of the GICT to education about recycling makes the museum an ideal showcase for its message, as well as an attractant for its Computerworks store where refurbished recent computers and computer parts are sold inexpensively. The store itself attracts members of the varied technology community in Austin, including retrocomputing hobbyists; hence a "virtuous cycle" has effectively acted to assemble skills and volunteers for the museum.

The core work of the GCM is supported by the volunteer efforts of a group of local electrical engineers with many years' experience in the computer industry and strong interests in retrocomputing. The GCM is not only committed to collecting legacy hardware, software, and documentation, but also aims to restore systems to working condition. To this end the museum makes use of the volunteers' professional-level skills in engineering, design, and fabrication of hardware and software. At the GCM, career technologists are involved with the significant cultural preservation activity of recovery and restoration.

Mobilizing their skills in the use of testing equipment and their familiarity with specification documentation, volunteers carefully test the functionality of newly received machines to ensure that they can be safely turned on and demonstrated. Where there is no documentation, their understanding of wiring, printed circuits, and computer components enables them to investigate and document how a machine ought to work. Where a machine is not immediately functional, they are able to find and replace malfunctioning parts and even to reengineer replacements for parts that are no longer available. The restoration process, drawing on the volunteers' skills and familiarity with standard procedures used in the industry, is a reverse-engineering, experimental process to recover machine functionality implied by visible circuitry and parts. This is clearly an example of placing volunteers' knowledge and skills at the service of preservation.

GCM and School of Information: Growing a Museum-Academic Collaboration

What follows is a reflective account of an emerging collaboration by the University of Texas (UT) School of Information (SI) with the GCM, where the importance of each partner to the other is seen by both as symmetrical for the purposes of achieving a range of mutual goals. The observations I offer of the developing relationship are based upon publicly available information only; except for one project, we have not yet begun studying ourselves. The source communities of information science and electrical engineering have significant overlaps, so from the beginning there were commonalities.

At the center of this collaboration there is also a set of objects of interest to all participants: computer hardware and software and the original and published documentation that support and address them, all of which are collected by the museum. Confronted with these objects, we bring different practices to bear: engineering practices around testing and restoration and information science practices around the construction of ontologies and information architectures. Together we seek to devise new museum practices that recognize and support the active use of artifacts for entertainment, education, preservation, and research. We also mobilize various interests depending on our group identities, including the specific goals of the GCM and its GICT parent and those of the SI and its University of Texas setting, and we aim to address or interact with the goals of others, including individuals, institutions, and businesses. In addition we are as individuals variously involved with existing museum and academic reward systems. Through the series of projects in which we have worked together so far, we have moved to collaborate more formally. I have framed this narrative as a process with stages, but as it is still very much ongoing, the frame must be provisional.

Stage One: Acquaintance

At first the relationship between the SI and the GCM was simply one of mutual attraction. Beginning in late 2007 our students began volunteering there, attracted by the legacy machines, which included a collection of early videogames, and the interest of a science museum. I was personally glad to find another historical museum in Austin to add to a list visited in a course I teach on historical museums. The museum was glad to have graduate students with archives, library, and information science skills who could assist with organizing holdings, putting together exhibits, and inventorying and arranging new acquisitions, especially printed and archival material, as part of the large formal accessioning of existing holdings in 2008–9. During this first stage of engagement, students played the role of volunteers at the museum. A few students could bring special skills to bear: creating a video kiosk that could serve as a window on the GCM's computer restoration activities without taking up much space; rehousing archival materials for better preservation and more efficient storage; revamping the museum's informal attempt at a conventional catalog to create a more robust database and testing it by recording a significant number of acquisitions.

Students found themselves in a context where authority for the core activity rests with the experts who created the museum and who had knowledge the students lacked. The authority of the GCM is based on the interests and skills of an authentic community of practice drawn from multiple levels of the computer business. But one stated goal of the GCM is to promote education about the history of computing, which allowed the students to fit in as beneficiaries: allowing graduate students' participation was just as much an evidence of the GCM's achieving that goal as was providing demonstrations for local middle schools. In addition, the museum has always advanced its ideas for exhibits through special projects carried out by volunteers, and as student volunteers worked there, they began also to develop projects they could do to contribute.

Stage Two: Investigating Shared Authority[2]

As it turned out, the SI had more to offer to the GCM, which emerged in the course of a developing relationship that began with a specific call for help. In my course in digital archiving, the initial task is to recover digital files. Since 2003 we have undertaken projects of archiving into the DSpace digital repository environment digital archival objects that form our own institutional archives. Since 2005 we have also undertaken projects as a digital archives incubator for the Harry Ransom Humanities Research Center, the Briscoe Center for American History (BCAH), and most recently the Alexander Architectural Archives, all three on the University of Texas campus. Until 2009 we had been able to cope pretty well with the more recent digital materials we were asked to work with, using current or relatively recent PC and Macintosh technology, by depending on backward compatibility of current or recent software.

During 2009, however, we began to tackle more complex collections dating to the 1980s. To bootstrap the preservation process, we sought the direct assistance of the GCM. Students were able to work there on several projects using Kaypro and Apple II computers from the GCM collections to recover files from the 1980s, working with the staff and volunteers at the museum to have hands-on experience with legacy hardware and software. This was a new activity for us *and* for the GCM, and it entailed improvising interfaces between older and newer machines and developing copying protocols. IT staff and faculty from the SI brought ideas to the table, students carried out online research in the retrocomputing literature and scoured the Web for relevant utilities, and GCM volunteers provided knowledge and skill in creating ad hoc interfaces between machines and software.

In the course of this work, we recognized our mutual preservation goals. The GCM has many digital objects in its possession in the form of computer design and user documentation and software, all of it just as much in need of preservation as the literary and historical materials we were working with. There were thus ample grounds in the interest in digital preservation on both sides for making an effort to bridge the social worlds of academia and computer-industry practices to craft a common ground (cf. Star & Griesemer, 1989). The GCM volunteers are already participants in the cultural preservation tasks of preserving documentation, hardware, and programming skills; preserving working machines and maintenance skills; and finally (fundamentally) preserving the ability to replicate and extend such skills. This work is comparable to what is being done actively on the international scene to preserve all kinds of intangible cultural heritage (UNESCO, 2003), yet because it takes place within an advanced technological culture, and because its subject is the *infrastructure* of that culture, it has so far remained invisible to the cultural heritage community (Star, 1991). The GCM initiative to preserve functioning legacy computing environments also suggests for us as archivists a very different and much more contextualized attitude toward the meaning of both “preservation of digital objects” and “community participation.” The GCM is not only a museum. It is also a repository of important documentation and publications that serve both as context for the hardware and software that were the original target of collecting and as important collecting goals themselves. Further, because its preservation practice also of necessity includes (re)discovery of undocumented or tacit knowledge, the GCM is also a laboratory for physical and digital preservation research.

In assisting archives faculty and students with solving problems of data capture, the skilled volunteers at the GCM also permitted us the opportunity of returning the favor by offering the skills we had that might potentially be of use to them and working together to discover how to build the archives and library aspects of the GCM as well as to perpetuate legacy technical skills. As we began to discuss issues like the formal creation of archival and library systems and creating a unified catalog to contain all of the museum's holdings, it became plain that the sharing would be thoroughgoing. What began to develop between us as we started to do projects together was a kind of truly balanced participatory action, in which we began to share competencies through experimental practice.

Stage Three: Joint Enterprise for Preserving Digital Culture

The GCM is not only an important resource with many opportunities to offer students of archival, library, and museum practice, but it is also an important experiment in institution-building and a set of laboratory experiments designed to achieve authenticity in restoration practice. Ongoing preservation, into the indefinite future, of outmoded electronic equipment and the allied problems this task entails, amounts in the aggregate to an experiment so far not yet attempted as seriously as here and extremely significant to our shared interest in the ongoing preservation of born-digital content. Because of these commonalities of interest, we have committed to become participants in the GCM community in a series of formal partnerships. Our contribution is to work actively with the museum on the preservation of its own materials, bringing archival, library, and museum practices as we understand them to bear (and to adapt them as necessary) to help systematize the capture and preservation of technical documentation, skills, and the physical performance of hardware and software, as well as the maintenance of a sustainable preservation environment for all of the GCM's collections. The several case studies below exemplify the varied forms this collaboration is taking.

Museum/Archives/Library Catalog. Because the GCM is primarily a museum, its focus is on the artifactual holdings: collections going forward will consist of "performance artifacts"; hardware and software; archival documentation of the artifacts in the form of original documents where available and recovered from retrocomputing websites; and a range of published materials, many of them now rare (including manuals, magazines, journals, books), to provide a context for the collections. We have begun to study together how the cataloging of the materials can assist in preserving living systems that will change over time. When master's student Walker Sampson undertook an individual study to improve the basic database recording the museum's holdings, it made sense to begin using aggregate cataloging methods for physical objects similar to the common usages of museums and archives to preserve provenancial groups, and it also made sense for objects to be cataloged using surrogates (photographs, videos, scanned schematics). The creation of a catalog to support all of these objects, as well as to serve as a repository for any of them that happen to be born digital, has entailed careful work on reconciling ontologies used in the cultural preservation world (for books, for example), with hierarchical metadata representations of the museum objects themselves and aggregate representations of both documentary collections and decomposable objects. We needed to provide for the detailed cataloging of some if not all of the small components of the system and its subsystems, and to figure out how to layer the data through devising a set of relationships. To do this usefully, it would be necessary to use industry nomenclature, sometimes standardized and sometimes not. The experts on this nomenclature and those who would be using it were the GCM volunteers. Working so closely to support the restoration process has led us to discuss the archival and museum literatures on the concept of the authenticity of maintained objects. In addition, we are interested in studying together how it is possible to translate the guidance of schematics and specifications, oral history research, and experiential data from the retrocomputing community into the preservation of genuine machine performance.

Ditto Project and Frankenstein I. The GCM was already a setting in 2009 for a significant research project ("Ditto"), an effort to recover empirically a proprietary file format that was never publicly documented and is now lost. This project has involved the construction of test equipment capable of recovering a disk image at the level of magnetic flux patterns that can then be examined statistically in order to establish hypothetical disk format structures for testing. It also constitutes a potential tool for the recovery of any unknown disk format on the basis of surviving media, and will therefore constitute a considerable assistance to the museum for the preservation of its holdings and to the digital archiving community in general. Our ongoing digital preservation work with actual collections of archival born-digital material will provide additional media for testing the equipment and protocols developed in this project. Further, we think that this technology will permit us to establish with more certainty the provenance (to a specific floppy drive, for example) of legacy media in provenanced collections where the collections include hardware.

Our need for assistance in recovering files from diskettes of known but noncurrent formats, together with the direction of research in the Ditto project, has led to a similar and less challenging effort. After our first semester of work with the GCM, which included work with the BCAH's Videogame Archive, students from the SI and Zach Vowell, digital archivist from the Briscoe Center, led the initial work on the construction of a legacy multimedia file-capture machine for digital preservation purposes, making use of legacy floppy drives at the GCM and informed by the engineers' understanding of disk technologies, track formatting, and driver programming—combined with archivists' ideas about what constitutes authenticity in digital objects and groups of digital objects. The building of this hardware was done at the museum in a collaboration between knowledgeable volunteers working with students and the archivist. We all realized its usefulness: the archival profession is beginning to recognize the importance of disk-image capture and techniques like digital stratigraphy to the preservation and analysis of digital objects (Kirschenbaum, Redwine, & Ovenden, 2010), while the museum itself holds programs and other files presently on legacy media and needing transfer for preservation. The following spring we transferred the machine to the school to support my class's archiving projects and thus to test the device. After intensive work with the first version of this machine, requirements for a more capable system supporting more media types and formats and operating systems are being developed toward the realization of a Frankenstein II during spring 2011.

Work-Practice in Restoration. All of us are especially interested in the knowledge, practical but undocumented as well as tacit, which make it possible to perform the task of preserving the performance artifacts, hardware, and software. The ongoing restoration work being done on the hardware collection at the GCM is a strong example of laboratory research. Restoration of nonfunctional systems requires examination of original archival documentation of design schematics and system specifications; or, where such documentation does not exist, empirical recovery and creation of such documentation to add to the archive. A good deal of experimental testing may be involved in this process, especially since the original machines may not in fact have met the specifications that are available for comparison.[3] Restored systems may then be tested with software from collections and their ability to execute appropriate software established. All of this work is professionally documented through engineering laboratory notebook recordkeeping practice.

But although this recordkeeping captures quite well the outcomes of restoration steps and documents the restored hardware and its functioning, it does not document the details of the reflective and experimental micropractices that accomplished the restoration. Our initial observation of this work has taught us much about the wealth of undocumented knowledge for working with legacy systems, still present in the digital engineering community but no longer being documented or passed along systematically as these systems become obsolete and therefore increasingly fragile. It seemed to me that a special focus on this knowledge, how to capture it, and especially how to reproduce it *within the scope of work of* *the museum*, could be an important research effort, for the GCM's own purposes and to address the broader challenge of preserving tacit technological knowledge (Galloway, 2009).

To pursue this aim, PhD student Carlos Ovalle is documenting workflows and apprenticeship knowledge transfers in which the museum volunteers act as masters, by carrying out work-practice observation to study the interaction of knowledge, tools, and nonfunctioning equipment in the restoration workflow, which is being analyzed to understand the network of people, objects, documents, and activities that enable the restoration. Through technology biographies, we are looking at how this knowledge has been perpetuated in the past in order to discover means of perpetuating it in the future, and we are carrying this task forward in full partnership with the volunteers using an action research framework. The museum director and the relevant volunteers are involving themselves in this effort to strengthen the museum's mission, and there are plans to expand the work of formal documentation of system restoration activities.

Computer-as-Collection Project. As an outgrowth of our interest in archival theory for working with archival corpora of born-digital documentary materials in undisturbed order, we had occasion to discuss with GCM partners the archival concept of provenance and our research into the literature on digital provenance. This discussion coincided with the developing trend of direct donation to the museum that has yielded so far at least one entire personal computer system from a known donor, complete with peripherals, software, documentation, and media, with the potential for interviewing the donor. This coincidence of interests has led to our setting up this collection as a project for determining what the documentation of such a body of materials should look like, how we can understand the aggregate collection as an environment, and how we can use digital forensic techniques to recover details of the use of the system and software. We are proposing that envisioning such a provenanced collection as an actor network of user, machine, software, documentation, and production will make it possible to better understand and address research questions connected with human relationships with technology. Discovering how to record these relationships will also support the museum's planning for the future collecting of provenanced groups.

Collaboration for Digital Heritage Preservation

When the relationship between the SI and the GCM began, both of us understood our missions as self-contained. For the GCM, the work of the nascent museum followed an initially simple cycle of production consisting of 1) processing recycling-stream input; 2) restoring computers to a functioning state; 3) creating interactive exhibits of computer history; 4) providing educational outreach to schools.

As the museum became more formalized, epicycles developed. First, the recycling stream remained a fruitful source of materials, but as people learned of the museum's existence, it attracted direct donations from people interested in older computers and unwilling to simply consign their systems to the anonymous recycling stream, and additional acquisitions led to a need for formal cataloging and classification systems. Second, more volunteer engineers joined the museum's restoration effort, bringing with them an increasingly broad range of skills. Third, additional exhibits were created and formal exhibit space was set aside. And fourth, educational efforts were expanded to include traveling exhibits and demonstrations. This growth required attention to administration and formalization to establish trustworthiness, which in its turn began to demand a range of skills that included a rather good fit with those that are part of postgraduate education in information studies.

The cycle of production at the SI, in which both faculty and students participate, is:

- students are admitted to pursue a degree;
- students pursue learning via organized coursework, volunteer experience, independent study, internship and capstone projects, and participation in faculty-led research;
- students receive a degree;
- faculty produce research.

Given the interest of the student alone, there is opportunity for no-credit volunteer work at the GCM; given the interest of faculty members, all of the other learning and research occasions represent possibilities for students to receive credit for participation with the museum.

SI course offerings concentrate in three areas: curation, organization, and interaction. Students are preparing to work in cultural institutions, government, and industry, and there is a strong component of technology throughout the program. Specific skills inculcated in individual courses, gained through more informal activities, or pertinent to research, are clearly relevant to the GCM's cycle of production. First, to the acquisition step students bring concepts of provenance and *fonds* from archival studies, individual and aggregate cataloging from library and archival studies practice, and development of collecting policies from cultural heritage institutional practice. Second, to the restoration step students and faculty bring new research on the preservation of tacit knowledge and the integration of retrocomputing enthusiasts' knowledge and findings. Third, to the exhibit step students bring new media approaches: ideas for sharing materials directly through an online catalog and for construction of virtual exhibits. Fourth, to the education step faculty bring research on transfer of tacit knowledge via apprenticeship and a developing understanding of computers as educational devices.

I believe that what we are learning from this collaborative work with the Goodwill Computer Museum frames a useful discussion of academic work with technology-oriented professionals to construct and contribute to the kind of institution needed to provide an adequate support for the preservation and reproduction of legacy technological culture. Where the community that supports a museum is also the community that genuinely bears the culture documented by the museum, the resulting strength of the institution is greater than a superficial inventory of its assets might suggest (Galloway, 2009; Karp, Kratz, Szwaja, & Ybarra-Frausto, 2007). Part of that strength lies in the ability of the museum to support both the experience of its subject matter by visitors and research based on and supportive of its collections. The GCM has emerged as the accretion of engineering skills around an interest in retrocomputing sparked by the availability of legacy computing machinery and software, in a sense developing an ontological practice around the material. In due course it has also attracted information science practitioners prepared to participate in and examine that practice in order to question aspects of an existing epistemology of preservation (Henare, Holbraad, & Wastell, 2007). We have come to see our work with the GCM as collaboration dedicated to the discovery and deployment of new cultural preservation practices: applications of electrical engineering *and* digital preservation research in aid of the broader goal of digital heritage preservation. The truly collaborative step will entail mutual effort to understand how we make this knowledge together. In that sense the GCM with its expert volunteers and its partnership with the SI is clearly a platform for research of many kinds touching on the full life cycle of information, from creation to preservation, as well as the infrastructure supporting it.

Notes

1. In this article I am addressing the case of digital objects of cultural value where experiential factors are deemed important to preserve; some of these concerns are not shared by government and business archivists for whom content alone is often of primary importance.
2. This expression of course refers to Michael Frisch (1990), while somewhat inverting his argument: Frisch pointed to the necessity for according adequate respect and authority to oral history informants; here we encounter the situation frequent in science and technology studies, where so-called "subjects" of research are more powerful in the eyes of the world than those who are investigating their practice, as in Knorr-Cetina (1999, pp. 17–25).
3. Although changes to specifications during manufacture are carefully recorded, these records are seldom archived once the machine has become obsolete, especially where the machine was not manufactured in huge numbers. See Galloway, in press.

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